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# How can process-based modelling improve tropical peat greenhouse gas emission factors?

**Erin Swails**[1], Kristell Hergoualc'h[1], Jia Deng[2], and Steve Frolking[2]
[1]Center for International Forestry Research, Indonesia
[2]Earth Systems Research Center, Institute for the Study of Earth, Oceans and Space, University of New Hampshire, USA

Degradation, conversion and drainage of tropical peatlands generate sizeable emissions of greenhouse gases (GHG). Current IPCC default emission factors (EF) for drained tropical peatlands are based on a very limited number of observations, thereby resulting in large uncertainties in emissions estimates. Impacts of disturbance on peat GHG emissions in undrained tropical peatlands can also be substantial but are not well characterized and not considered by IPCC guidelines. Research is critically needed to support development of more accurate EF for national GHG accounting for both drained and undrained degraded tropical peatlands. To explore the potential of process-based modelling to refine tropical peat EF, we used the DeNitrification DeComposition (DNDC) model to simulate peat GHG emissions and biogeophysical variables in oil palm plantations and undrained primary and secondary peat swamp forests of Central Kalimantan, Indonesia.

The simulated magnitude of C inputs (litterfall and root mortality) and dynamics of annual heterotrophic respiration and peat decomposition $N_2O$ fluxes in oil palm plantations were generally consistent with field observations. The modelled onsite oil palm peat $CO_2$ EF was lower than the IPCC default (11 Mg $CO_2$-C ha$^{-1}$ yr$^{-1}$) and decreased from 7.7 ± 0.4 Mg C ha$^{-1}$ yr$^{-1}$ in the first decade to 3.0 ± 0.2 and 1.8 ± 0.3 Mg C ha$^{-1}$ yr$^{-1}$ in the second and third decades of the rotation. The modelled $N_2O$ EF from peat decomposition was higher than the IPCC default (1.2 kg N ha$^{-1}$ yr$^{-1}$) and increased from 3.5 ± 0.3 kg N ha$^{-1}$ yr$^{-1}$ in the first decade to 4.6 ± 0.5 kg N ha$^{-1}$ yr$^{-1}$ in the following ones. Modelled fertilizer-induced $N_2O$ emissions were minimal and much less than 1.6% of N inputs indicated by the IPCC EF in wet climates regardless of soil type. Temporal variations in oil palm EF were strongly linked to soil C:N ratio and mineral N content for $CO_2$ and fertilizer-induced $N_2O$ emissions, and to precipitation, water table level, and soil $NH_4^+$ content for peat decomposition $N_2O$ emissions. These results suggest that current IPCC EF for oil palm on organic soil could over-estimate onsite $CO_2$ emissions and underestimate peat decomposition $N_2O$ emissions and that decadal-scale temporal variation in emissions should be considered for further improvement of EF. Simulations allowed the generation of oil palm EF disaggregated by plantation age and emission source (decomposition, fertilizer-induced), a practical and useful application for GHG inventories in tropical peatlands.

In unconverted land uses, the GHG budget (Mg $CO_2$-equivalent ha$^{-1}$ yr$^{-1}$) was ten times higher in

the secondary forest (10.2 ± 4.5) than in the primary forests (0.9 ± 3.9) on the account of a larger peat C budget and $N_2O$ emission rate. Preliminary modelling results suggest increased peat C outputs from heterotrophic respiration and decreased C inputs from litterfall and root mortality in secondary forest compared to primary forest. Our study highlights the disastrous atmospheric impact associated with not only conversion to oil palm but also forest degradation in tropical peatlands and stresses the need to investigate GHG fluxes in disturbed undrained lands.